Macroinvertebrate Community Structure and Physicochemical Conditions of a Northwestern Oklahoma Spring

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Abstract: Little Boiling Spring is a small rheocrene spring located in northwestern Oklahoma emerging from a sandy substrate and eventually flowing into the North Canadian River. Macroinvertebrate collections and water quality measurements were recorded seasonally for an annual period at the springhead and in the springbrook. A total of 31,376 individuals representing 49 taxa were collected in Surber net samples, while an additional three taxa were collected using a dip net. The spring fauna was dominated by worms, crustaceans, and dipterans. Shannon's species diversity values at the springhead differed significantly from those in the springbrook during all seasonal collections, most likely due to increasing levels of oxygen and detritus documented during each collection in the springbrook. Collectors were the most abundant trophic group present in the spring throughout the investigation.

Introduction

Springs are described as naturally occurring sources of emerging groundwater having unique properties, such as discrete habitats with relatively constant conditions with respect to temperature, dissolved oxygen concentration, and flow (van der Kamp 1995). Only a few ecological studies of these special environments have occurred in Oklahoma. Matthews et al. (1983) attempted to determine whether macroinvertebrate community compositions could be useful indicators of groundwater quality, but low similarities between the springs in the study led to inconclusive results. Varza and Covich (1995) concluded that limited food availability and predation by crayfish limited macroinvertebrate abundance in Buckhorn Spring. Bass (2000) reported a combined total of 39 taxa of macroinvertebrates from two springs in the Pontotoc Ridge Nature Preserve sampled during 1995. Based on samples of invertebrates from six springs along a southeast to northwest gradient across Oklahoma, Gaskin and Bass (2000) concluded a unique spring fauna was generally not present in Oklahoma and the spring inhabitants were associated with populations from other nearby stream habitats. Rudisill and Bass (2005) reported 64 taxa, dominated by dipteran larvae, during a year-long investigation from three adjacent springs in Roman Nose State Park. Graening et al. (2006) compiled a checklist of all amphipods known from subterranean habitats, including springs, in Oklahoma. Three springs in south-central Oklahoma yielded 114 invertebrate taxa over an annual period, dominated by the species complex *Hyalella azteca* and *Tanytarsus* (Brown and Bass 2014). Bass et al. (2017) found 49 invertebrate taxa, dominated by insects, especially larval Chironomidae, in another year-long investigation inhabiting Desperado Spring, a small, rocky spring flowing into the Blue River in south-central Oklahoma.

During the same annual period as the Desperado Spring investigation (Bass et al. 2017), a parallel study was being conducted at Little Boiling Spring in northwestern Oklahoma. The macroinvertebrate community of Little Boiling Spring had been previously sampled by Gaskin and Bass (2000).

Purposes of the current investigation were to 1) describe the macroinvertebrate community composition of Little Boiling Spring over an annual period, 2) compare composition of these communities to previously collected data on this and other springs, and 3) determine selected physicochemical conditions of Little Boiling Spring.

Methods

Little Boiling Spring is a rheocrene spring located in Boiling Springs State Park of northwestern Oklahoma in Woodward County (36.4541°N, 99.2876°W). The spring emerges from a sandy substrate and flows approximately 500 meters before reaching the North Canadian River. The emergence pool at the head is approximately 2 m in diameter and less than 0.5 m deep while the run measured about 0.5 m in width and almost 0.1 m in depth. The substrate of the run is composed primarily of sand, with an abundance of aquatic vegetation, as well as decomposing leaf and wood debris (Gaskin and Bass 2000).

Little Boiling Spring was sampled seasonally (October, January, April, and July) beginning in 2002. Both physicochemical and macroinvertebrate samples were collected during each quarterly visit. Two sampling sites (springhead and approximately 25 m downstream in springbrook) were established and three Surber net samples were collected from each site. Qualitative samples were also collected, by examining microhabitats using a dip net, to capture species that may have been missed by the Surber net. All samples were washed in a number 60 (0.250mm) U.S. standard sieve bucket and preserved with a 10% mixture of formalin and Rose Bengal dye. The preserved macroinvertebrates were returned to the laboratory to be sorted, identified, and counted. Identification of macroinvertebrates was determined primarily using keys by Wiederholm (1983), Epler (1995), Smith (2001), Merritt et al. (2008), and Thorp and Covich (2009). All specimens were deposited in the Invertebrate Section of the University of Central Oklahoma Natural History Museum.

Shannon's (1948) diversity index was calculated for springhead samples and springbrook samples during each collection period. Sorenson's index of similarity (Brower et al. 1997) was used to make comparisons between the species present at the springhead and the springbrook sites for each collection. Chi-square contingency analyses were performed to determine if there was a relationship in the number of individuals between the springhead and the springbrook during the different seasons. Finally, a Hutcheson *t*-test was used to compare species diversity between the springhead and the springbrook samples (Zar 2010).

Water temperature, dissolved oxygen concentration, and pH were measured at both the springhead and the springbrook, while alkalinity and flow were measured only at the springhead (American Public Health Association 1999). In addition, a water sample collected from the springhead was used to determine turbidity, conductivity, and concentrations of ammonia, nitrites, nitrates, and orthophosphates in the laboratory using a Bausch & Lomb Spectrophotometer 20 (Hach 1987).

Results and Discussion

Results from the analysis of the physicochemical conditions taken at each collection date indicated the water quality is sufficient to support aquatic macroinvertebrates (Table 1). Both dissolved oxygen concentration and percent oxygen saturation values increased between the springhead and springbrook sites as atmospheric oxygen diffused into the water below the emergence point (van der Kamp 1995). The values of most other parameters

Table 1. Physicochemical conditions measured at the springhead in Little Boiling Spring, Boiling Springs State Park, Woodward County, Oklahoma. Values in parentheses describe conditions in springbrook.

Parameter/Collection	Oct. 2002	Jan. 2003	Apr. 2003
Water Temperature °C	17.5 (17.3)	15.3 (15.5)	16 (16.4)
Dissolved Oxygen (mg/l)	4.5 (7.4)	4.6 (7.2)	5.1 (8.5)
DO Percent Saturation	45 (75)	43 (75)	43 (85)
pH	6.9 (7.3)	7.4 (7.6)	7.5 (7.5)
Alkalinity (mg/l)	175	185	169
Carbon Dioxide (mg/l)	38	13	9
Turbidity (JTU)	3	2	3
Specific Conductivity (umhos/cm)	620	668	610
Ammonia (mg/l)	0.27	0.27	0.23
Nitrates (mg/l)	0.88	0.73	0.88
Nitrites (mg/l)	4	11	2
Orthophosphates (mg/l)	0.33	0.17	0.17
Flow (m/sec)	0.2	0.2	0.2

were relatively constant.

A total of 31,376 individuals representing 49 species were collected in the Surber net samples during the four seasonal sampling periods from Little Boiling Spring (Table 2). In addition, a single species of decapod and two species of coleopterans were collected only in the qualitative samples, so they were not included in the statistical analyses. Hexapods made up 39.9% of the individuals and 36 taxa, while non-hexapods formed 61.1% of the individuals and 13 species. This overwhelming dominance by crustaceans, particularly the species complex *Hyalella azteca,* is similar to what was reported by Brown and Bass (2014) in the Pontotoc Ridge springs of southeast Oklahoma. It is well known that springs often support more non-insects than insects (Webb et al. 1995; Brown and Bass 2014), and this was certainly the case with Little Boiling Spring. Although the number of individuals was lower among the hexapods, there were almost three times more species of hexapods than non-hexapods in the spring. This is most likely because the springbrook flows into the nearby North Canadian River, an environment supporting many aquatic insects, so its fauna may easily colonize the spring environment (Gaskin and Bass 2000).

Six genera dominated the Little Boiling Spring macroinvertebrate community with each one constituting greater than five percent of the total number of individuals and collectively making up almost 70% of the individuals present in the collections. These included the annelid *Limnodrilus* sp. (7.3%), an unidentified nematode (7.9%), amphipods of the *Hyalella* *azteca* species complex (12.0%), Podocopida ostracods (25.8%), and the chironomid larvae *Eukiefferiella claripennis* (9.9%) and *Larsia* sp. (6.9%). *Eukiefferiella claripennis and Larsia* sp. always occurred in higher numbers at the springhead, while *Limnodrilus* sp., unknown Nematoda, *Hyalella azteca* species complex, and Podocopida were consistently more abundant in the springbrook (Table 2). It is possible these distributions reflected preferences for different microhabitats – the springhead substrate was composed primarily of sand, while the springbrook substrate contained a greater amount of plant detritus overlying the sand. It is likely inhabitants of the springhead preferred the sand for burrowing and the springbrook species required the greater organic content present with the detritus.

Comparisons of the species present at the springhead and those present at the springbrook sites using Sorensen's index of similarity yielded values ranging from 0.37 - 0.41 during the four collection periods. Specifically, those numbers were 0.41 during October, 0.41 during January, 0.37 during April, and 0.40 during July. Although some species did occur at both sites, other species were limited to either the springhead or the springbrook (Table 2).

Results from the chi-square analyses indicated there was a statistically significant relationship between the number of individuals in the springhead and springbrook collections during all four seasons (χ^2 contingency test, $p<0.00001$). Shannon's diversity values at the springhead ranged from 1.985 - 2.656 while these values in the springbrook were 1.642 - 2.351 (Table 2). Hutcheson *t*-test showed a significant difference in species diversities between the springhead and springbrook for each collection month (October t=12.564, $p<0.0001$; January t=4.146, $p<0.0001$; April t=7.991, $p<0.0001$; July t=8.244, $p<0.0001$) (Fig. 1). As noted in other Oklahoma spring studies (Bass 2000; Rudisill and Bass 2005; Bass et al. 2017), dissolved oxygen concentrations increased, presumably from atmospheric diffusion, as water flowed from the springhead into the springbrook, allowing the springbrook to support different species of macroinvertebrates. There was also more detritus present in the springbrook serving as food and microhabitat for these species. Although the species richness during each sampling period showed little variation between the springhead and springbrook, a greater number of individuals were found in the springbrook, leading to lower Shannon's species diversity values for the springbrook collections (Brower et al. 1997).

Collectors dominated Little Boiling Spring based on trophic catagories in Merritt et al. (2008) and Thorp and Covich (2009). Collectors were composed of 29 taxa and made up 81.3% of the individuals present. Predators (15 species, 17.8% of the total individuals) and detritivores (five species, 0.9% of the total individuals) composed the remaining trophic groups in the community. It should be noted that in addition to emergence of adults from the spring, some of these species have different trophic roles as they grow and mature (Merritt et al. 2008), so these proportions may change through time.

A large fraction of insect nymphs and larvae were found in the samples (Table 2). Gaskin and Bass (2000) also observed many immature

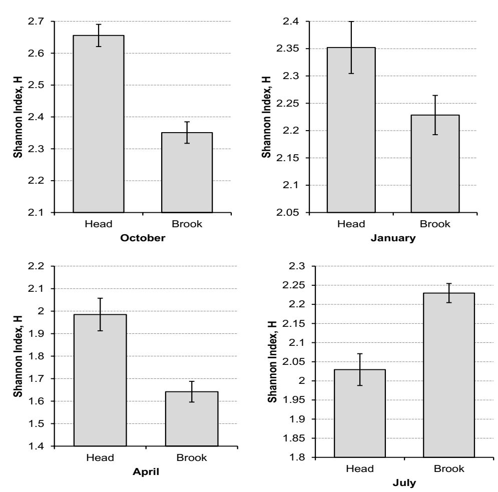

Figure 1. Box charts displaying the variation in diversity between springhead and springbrook samples in Little Boiling Spring for each month of data collection.

Table 2. Macroinvertebrates collected in Little Boiling Spring, Boiling Springs State Park, Woodward County, Oklahoma.

Taxa	Oct. 2002 Springhead	Oct. 2002 Springbrook	Jan. 2003 Springhead	Jan. 2003 Springbrook	Apr. 2003 Springhead	Apr. 2003 Springbrook	Jul. 2003 Springhead	Jul. 2003 Springbrook	Totals
Platyhelminthes									
Dugesia sp.	48	65	86	44	25	40	109	180	597
Gastropoda									
Physa sp.	66	97	59	116	5	24			367
Bivalvia									
Sphaerium sp.		148		107	2	123	4	172	556
Annelida									
Dero sp.	45	24		2	6	8		202	287
Helobdella triserialis				1	1				2
Limnodrilus sp.	108	505	9	981	40	260	9	377	2289
Lumbriculus sp.	13	48	4	1	4	5			75
Nematoda									
Nematoda	93	1445	38	471	11	107	27	300	2492
Crustacea									
Harpacticoida	148	12	15	40		1			216
Hyalella azteca complex	258	477	225	326	125	415	389	1564	3779
Podocopida	4	279	22	1410	25	2882	403	3078	8103
Cambaridae *									*
Collembola									
Isotomidae	3		3		2		4	1	13
Sminthuridae	1				1	1		4	7
Ephemeroptera									
Baetis sp.	1	8	25	37	2	196	1	494	764
Stenonema sp.				2					2
Odonata									
Argia sp.	87	93	142	90	145	195	107	163	1022
Coenagrionidae	344	170	401	238			49	25	1227
Orthoptera									
Acrididae					1			1	2
Hemiptera									
Aquarius sp.						1		3	4
Belostoma sp.							1		1
Coleoptera									
Agabus sp.					1				1
Celina sp.							1		1
Hydraenidae						1	5		6
Laccophilus sp.*									*
Matus sp.*									*
Paracymus sp.	1					1			2
Tropisternus sp.			2						2

Table 2 Continued

Taxa	Oct. 2002 Springhead	Oct. 2002 Springbrook	Jan. 2003 Springhead	Jan. 2003 Springbrook	Apr. 2003 Springhead	Apr. 2003 Springbrook	Jul. 2003 Springhead	Jul. 2003 Springbrook	Totals
Diptera									
Chironomus sp.				2			9		11
Corynoneura sp.	106	111	43	2	102	90	9	9	472
Cricotopus sp.			5	7	22	39	7	28	108
Cryptochironomus sp.		5	5	168	4	15	7	133	337
Dasyhelea sp.	113	395	10	29	12	72	8	103	742
Dicrotendipes sp.				2					2
Dixella sp.			4	1	1		3	10	19
Djalmabatista sp.				2					2
Eukiefferiella claripennis	453		247	43	670	81	935	684	3113
Labrundinia sp.	3	2				17	10	30	62
Larsia sp.	186	144	374	139	135	36	880	284	2178
Nemotelus sp.						1			1
Paratendipes sp.						2			2
Polypedilum halterale	228	217	117	40	40	6	143		791
Simulium sp.	8	44	4	92	1	7	3	607	766
Stratiomyidae	35						2		37
Stratiomys sp.	32		2		19				53
Tanytarsus sp.	15	1	28	2	24	49	53	269	441
Tipula sp.	5	18	1	13	8	4		2	51
Trichoptera									
Hydroptila sp.	4	21	8	11		4	21	33	102
Setodes sp.		66	1	53		15	7	2	144
Lepidoptera									
Crambidae		1			1		19	2	23
Acarina									
Hydrachnidiae 1	74	4	1				14		93
Hydrachnidiae 2			1	2			5	1	9
Number of Individuals	2482	4400	1882	4474	1435	4698	3244	8761	31376
Species Richness	28	26	29	32	29	31	31	29	49 + (3*)
Species Diversity	2.656	2.351	2.352	2.228	1.985	1.642	2.029	2.230	2.625

*** indicates taxa were not present in Surber net samples; found only in qualitative samples and not used in the statistical analysis.**

insects present in Little Boiling Spring and suggested reproduction must have been occurring there. This may have been the case, but another possibility was suggested by Bass et al. (2017) regarding a similar situation in Desperado Spring. Individuals making up the spring populations may have originated in the nearby river and later moved into the springbrook, using it as a refuge from larger predators, such as fishes, that would have difficulty existing in the spring's shallow water. It is unknown which, if either, of these hypotheses correctly explains the high number of immature individuals in Little Boiling Spring, but they are both possibilities.

It was mentioned previously that this Little Boiling Spring investigation was being done concurrently with the study of Desperado Spring (Bass et al. 2017). Although the same number of taxa, 49, was collected in the Surber net samples from both Little Boiling Spring and Desperado Spring, there was not much species similarity between the two springs. They shared only 23 taxa, resulting in a Sorenson's similarity value of 0.235. Besides these springs existing at opposite ends of Oklahoma geographically, Little Boiling Spring is located in the Central Great Plains ecoregion while Desperado Spring occurs in the Cross Timbers ecoregion (Oklahoma Forestry Services 2018), resulting in considerable physical differences between the two sites. Similarity values are reduced as different species are adapted to those variations in the local environments, such as substrate type, detrital composition, and water quality parameters.

It may be of interest to note Gaskin and Bass (2000) reported 14 species from Little Boiling Spring during 1999, many of which were also collected in the present investigation. However, the 1999 study sampled that site only once and used different methodology for collecting. The present investigation sampled a larger section of the spring site and made seasonal collections, resulting in finding a total of 52 taxa. This shows the value of increasing sample size, employing several sampling methods, and making collections over an annual period to assure obtaining a more complete description of community structure.

Conclusion

Springs are unique and often over-looked aquatic environments. While many springs are reported to contain fauna found nowhere else, the Little Boiling Spring invertebrate community contains many species also found in the nearby North Canadian River. Crustaceans are the dominant group in many springs and this phenomenon was also observed in Little Boiling Spring, However, due to its close proximity to the North Canadian River, chironomids were abundant as well. Results of the physicochemical conditions in Little Boiling Spring indicated the water quality is capable of supporting a diverse biota and this was confirmed by the intolerant taxa present in the samples.

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